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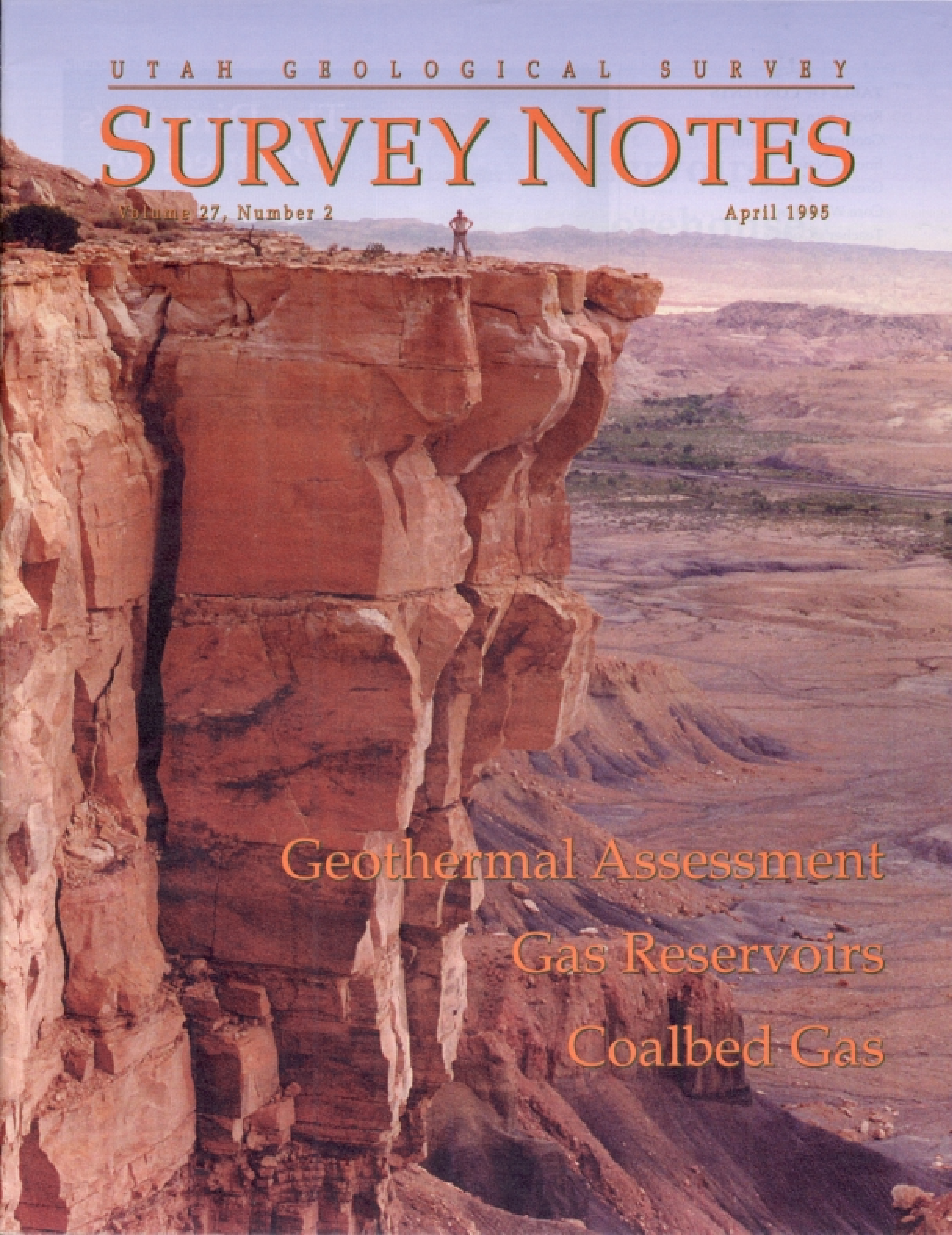

Geothermal Assessment

Gas Reservoirs

Coalbed Gas

TABLE OF CONTENTS

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The Director's Perspective

by M. Lee Allison

Halting the Oil Decline

The Utah Geological Survey is embarked on a long-term mission to halt and possibly even reverse the decline of oil production in Utah.

In less than 10 years, Utah's production has dropped more than 47 percent and continues to decline as much as 7 percent annually. The resulting loss of jobs and taxes has been devastating to the state's principal oil-producing counties of San Juan, Duchesne, Summit and Uinta. In 1985, the peak production year preceding the collapse of the world oil price, Utah produced nearly 41 million barrels of oil, or over 112,000 barrels per day. The value of oil sold that year was about $986 million (in 1984 it actually exceeded $1 billion). This was enough to make Utah number 11 among all states in oil production.

In 1993, production amounted to less than 22 million barrels, or 60,000 barrels per day, which sold for a total of $380 million.

During the same period, imported oil rose to over 50 percent of U.S. consumption, the highest percentage in our history. This over-dependence on foreign oil is a major contributor to the U.S. balance of payments problem and makes the country even more vulnerable to energy blackmail than during the 1973 oil embargo.

To address this problem, the UGS has assembled a first-rate team of petroleum geologists with extensive oil industry background to help ensure the economic vitality of one of Utah's largest and most important industries. The UGS program is multifold: cooperative field demonstration projects with producing oil companies; joint efforts with counties and state agencies to identify and promote new exploration and development targets; and an aggressive technology transfer program to get new ideas, concepts, and techniques into use as quickly as possible by both industry and government.

In the Uinta Basin, the UGS is teamed with three oil companies, a number of oil field service companies, and university researchers to find better ways to complete oil wells in the giant Bluebell field. Reservoir engineering analyses by the UGS team found that as little as 2-4 percent of the original oil-in-place is being recovered by wells in the field. Nationally, 15-30 percent is more typical. By the summer of 1995, we hope to put our ideas to work in revitalizing two Bluebell wells operated by Quinex Energy of Bountiful, Utah. Ultimately, if we can just double the recovery factor in basin wells, Utah could see an additional 500 million barrels of oil produced that might otherwise be left behind and lost.

In the Paradox Basin of San Juan County, the UGS recently initiated a cooperative project with an independent oil company, Harken Southwest, on small "algal-mound" (reef-like features) type oil fields on the Navajo Nation. It has been estimated that as much as 85 percent of the recoverable oil is being left behind in these fields. The UGS-Harken partnership will implement and evaluate a water or carbon dioxide "flood" to drive out additional oil from one of five candidate fields. If we can

Continued on page 15 . . .

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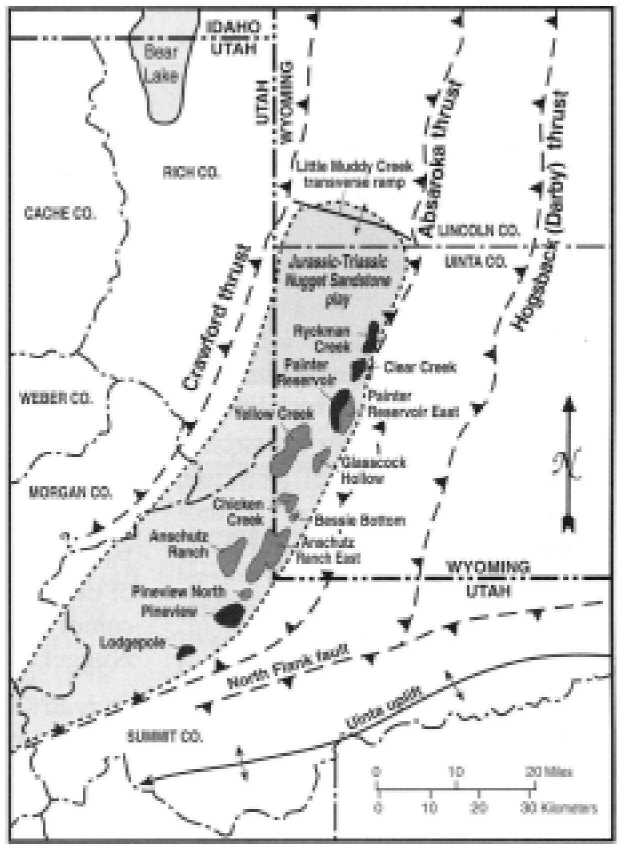
Rocky Mountain Gas Reservoirs - America's Natural Gas Storehouse

by Thomas C. Chidsey, Jr.

The Rocky Mountain region may hold as much as 35 and 120 trillion cubic feet (TCF) of proven and potential natural-gas resources respectively. These numbers attest to the tremendous potential for increasing recovery from existing reservoirs and finding new reserves. New pipeline construction, drilling and recovery technology, and coalbed-methane development make the future look bright for Rocky Mountain gas, especially in Utah. During the past two years, 30 of the 51 companies new to Utah have initiated field development or exploration programs for gas.

To assist with the exploration and development efforts of the petroleum industry, the geological surveys of Utah, New Mexico , Wyoming, and Colorado produced the "Atlas of Major Rocky Mountain Gas Reservoirs" and an accompanying database. The major gas reservoirs, plays, and play suites in the four states are identified and described in the atlas. A **gas reservoir** is a single, discrete, subsurface layer of porous and permeable rock storing gas and/or oil. The atlas defines a major gas reservoir as one which has produced over 5 billion cubic feet (BCF) of gas as of January 1, 1991. For example, the Tertiary-age (62 million years old) Green River Formation in the Uinta basin of eastern Utah is a major Utah oil and gas reservoir. In the Bluebell field of Duchesne and Uintah counties, the Green River Formation has produced over 130 million barrels of oil and 160 BCF of **associated gas** (associated gas is gas produced with oil). There are 64 major gas reservoirs in Utah.

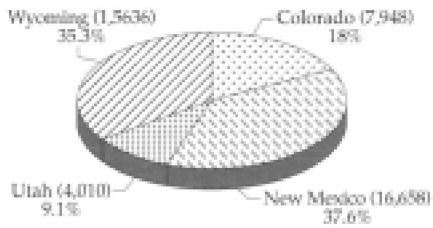
A **play** is group of major reservoirs in a geographic area with a common stratigraphic unit, rock type, depositional environment or structural setting, and hydrocarbon-trapping mechanism. For example, the Jurassic-age (180 million years old) Nugget Sandstone play in the Utah/ Wyoming thrust belt represents the most productive gas play in Utah, having produced over 1.2 TCF of gas — most production coming from the giant Anschutz Ranch East field in Summit County. The smallest play in Utah, the Triassic-age (230 million years old) Dinwoody Formation play, is also in the Utah/Wyoming thrust belt. The play consists of one reservoir tapped by one well in one field, Hogback Ridge field (now abandoned) in Rich County, and produced only 5.5 BCF of gas. There are 23 major gas plays identified in Utah.



The Nugget Sandstone play (shaded) and oil and gas fields (solid areas) which produce from the Nugget Sandstone in the Utah/ Wyoming thrust belt. Major thrust faults are dashed where approximate (teeth indicate hanging wall).

A **play suite** is a group of plays in broad geographical areas sharing a common geological theme. Play suites may have a common stratigraphic age or basinal/tectonic settings. For example, the Utah/ Wyoming thrust belt play suite contains seven major plays representing 34% of Utah's gas production. Eight play suites are identified in Utah.

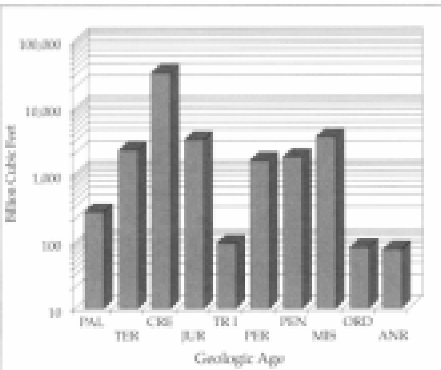
New Mexico has produced the greatest amount of gas in the Rocky Mountains, primarily from Cretaceous-age (130 million years old) reservoirs and plays in the San Juan



Total cumulative gas production as of January 1, 1991 (in BCF).

basin in the northwestern part of the state. New Mexico is followed in total gas production by Wyoming, Colorado, and Utah. Three-fourths of all production is **nonassociated gas** (gas produced without oil but it may include natural gas liquids such as condensate), indicating the high potential for natural gas in the region. Reservoirs which produce nonassociated gas typically contain significantly larger gas reserves than those which produce associated gas.

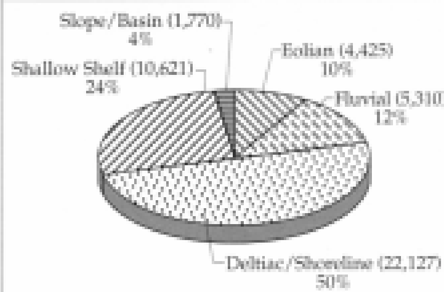
Statistical analyses of the data compiled from the reservoir database in the atlas targets the age, depositional environment , reservoir rock litholo-



Distribution of gas production by geologic age of the reservoirs in the four states (in BCF). PAL = Paleocene; TER = Tertiary undifferentiated; CRE = Cretaceous; JUR = Jurassic; TRI = Triassic; PER = Permian; PEN = Pennsylvanian; MIS = Mississippian; ORD = Ordovician; ANR = age not reported.

gy (rock type), and trapping mechanism for exploratory and enhanced recovery efforts. The majority of the gas production in the four states comes from Cretaceous-age reservoirs. In Utah, the Frontier Formation, Ferron Sandstone, Dakota Sandstone, and Mesaverde Group are the major Cretaceous gas reservoirs.

Nearly half the gas production comes from rocks deposited in a deltaic/shoreline environment. Other important sources include shallow shelf (marine carbonates), fluvial (river), and eolian (sand dune) envi-

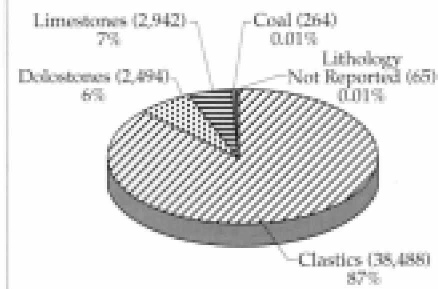


Distribution of gas production by reservoir depositional environment in the four states (in BCF).

ronments. In Utah, most gas production in the Uinta basin comes from fluvial-deltaic deposits in the Tertiary Green River and Wasatch Formations, and the Cretaceous Mesaverde Group. In the Paradox basin, all Utah production comes from shallow-shelf deposits of the Mississippian-age (360 million years old) Leadville Limestone and Pennsylvanian-age (320 million years old) Paradox Formation. In the Utah part of the thrust belt, most production comes from eolian deposits of the Nugget Sandstone.

Over 87% of the gas in the four states is produced from **clastic rocks**, principally sandstones (clastic rocks consist of fragments of rocks that have been moved from their place of origin). Other important rock types include limestones, dolostones, and coal . In Utah, most of the gas production in the thrust belt, Uinta basin, and Uncompahgre uplift comes from sandstones. In the Paradox basin, gas production is from limestones and some dolostones. Gas production from coal (coalbed methane) has been established in Utah near the town of Price, Carbon County (see Survey Notes, v. 25, no. 3-4, p. 13-15).

Over 50% of the gas produced in the four states accumulated in stratigraphic traps with the remaining equally divided between structural and combination traps. A **stratigraphic trap** is a hydrocarbon trap formed when the reservoir rock is terminated by nonreservoir rock (such as an ancient river sandbar surrounded by shale) or a change of porosity or permeability within the reservoir rock itself. A **structural trap** is formed from folding and/or faulting of the reservoir rock. A **combination trap** is partly stratigraphic and partly structural. In Utah, all of the thrust belt gas production comes from structural traps. In the Uinta basin, 65% of the gas is produced from stratigraphic traps and 35%



Distribution of gas production by reservoir lithology in the four states (in BCF).

from combination traps. In the Paradox basin, 90% of gas is produced from combination traps, 7% from stratigraphic traps, and 3% from structural traps.

The "Atlas of Major Rocky Mountain Gas Reservoirs" and statistical analyses of the database compiled for the atlas, provide a quick but accurate understanding of the reservoir, play, and play-suite characteristics in Utah for petroleum geologists. Other potential users of the atlas include: (1) utility companies and manufacturers, (2) pipeline companies and gas processors, (3) bankers and investors, and (4) petroleum engineers, landmen, and economists.

The "Atlas of Major Rocky Mountain Gas Reservoirs", including 10 plates and the database on diskette, may be purchased for $95 plus tax at the Utah Geological Survey or ordered from the New Mexico Bureau of Mines and Mineral Resources. ■

Results of the 1993 Low-temperature Geothermal Assessment Program in Utah

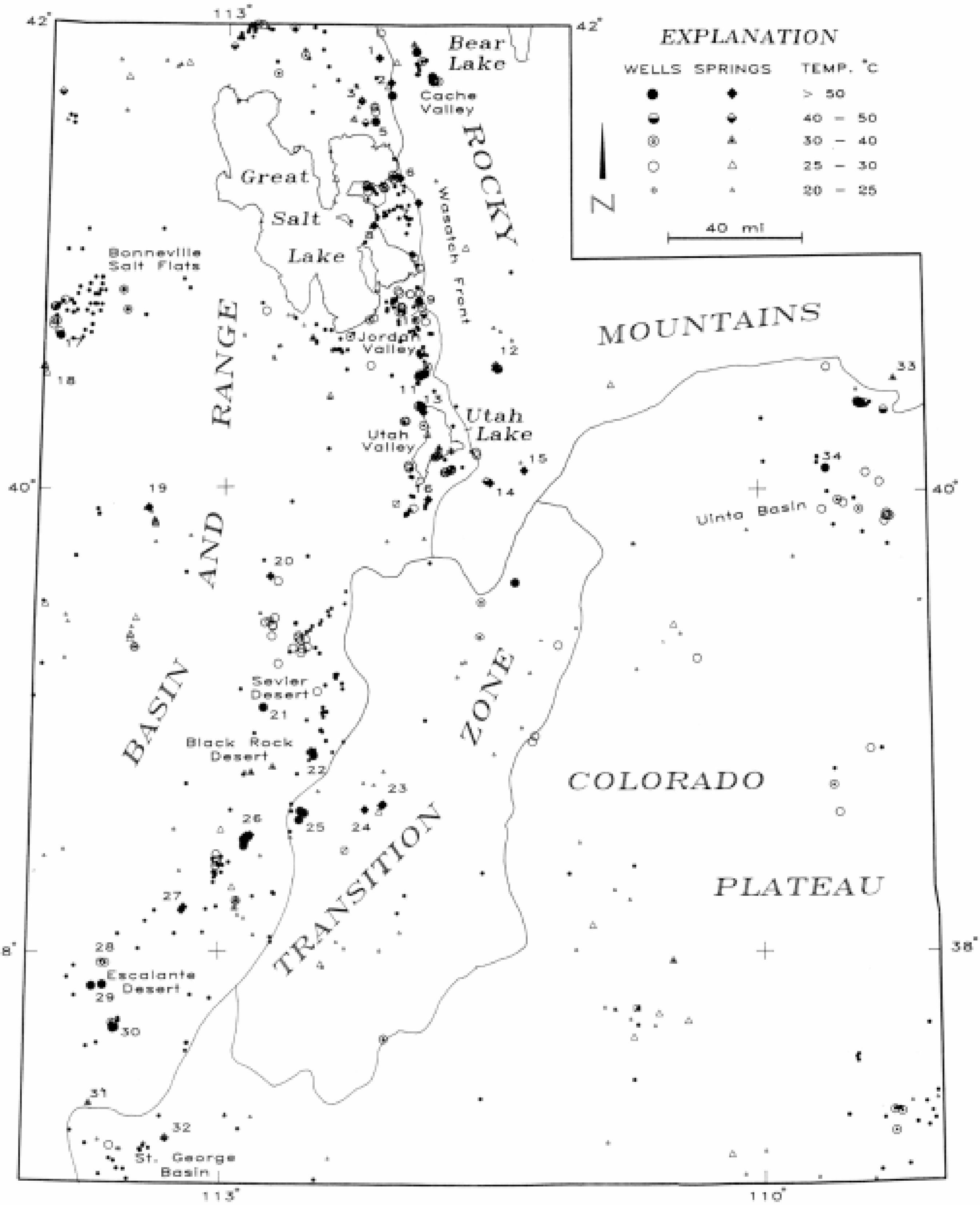
by Robert E. Blackett

Summary
The new geothermal database for Utah (UGS Open-File Report 311) contains data from a previous geothermal assessment plus a considerable amount of new data (more than double the wells and springs compiled previously). It is comprehensive and accessible through personal computer to provide detailed geothermal information. It contains 964 records on 792 wells and springs derived from available non-proprietary sources through 1992. Each record has 35 data fields and includes the location of the well or spring, temperature, depth, flow-rate, and chemical constituents. With few exceptions, data from deep oil and gas wells and thermal-gradient boreholes are not in the database but will be incorporated as the OFR is updated.

The Utah Geological Survey (UGS) recently compiled a database with information on thermal wells and springs in Utah as part of a 10-state, U.S. Department of Energy (DOE) program. The database, which contains 35 data fields and includes 964 records for 792 well and spring locations with temperatures of 20°C (68°F) or more, is available to the public in UGS Open-File Report 311. It is comprehensive and personal-computer (PC) oriented to provide users with ready access to detailed geothermal information on Utah. The Geothermal Division of DOE initiated the Low-Temperature Geothermal Resources and Technology Transfer Program following a special appropriation by Congress in 1991, to encourage energy conservation through wider use of lower temperature geothermal resources. Low-temperature geothermal resources can be used directly for space-heating, in industrial processes, and for geothermal (ground-source) heat-pumps. The Oregon Institute of Technology (OIT), the University of Utah Research Institute (UURI), and the Idaho Water Resources Research Institute organized the federally funded program and enlisted the help of 10 western states to carry out the first phase of the program. For this phase, the participating state agencies inventoried thermal wells and springs. The UGS performed this inventory for Utah.

In the early 1980s, the U.S. Geological Survey (USGS) compiled the first comprehensive database of geothermal wells and springs in Utah as part of a national geothermal assessment. The data from this assessment were incorporated into a main-frame computer system called GEOTHERM. GEOTHERM received data until it was taken off-line in 1983. The UGS compiled the Utah data for GEO-THERM and published a state geothermal resource map in cooperation with DOE and the National Oceanic and Atmospheric Administration. The map listed about 330 wells and springs included in GEOTHERM, showed heat-flow information, and outlined areas of prospective value for geothermal exploration. The map also showed nine Known Geothermal Resource Areas (KGRAs), a classification for federal leasing based on competitive interests and/or geologic criteria. Since 1980, only three of these areas (Cove Fort-Sulphurdale, Roosevelt Hot Springs, and Crater Springs) still retain the classification of KGRA. Not since the national geothermal assessment was completed in the early 1980s have new geothermal-resource data been compiled.

Phase one of DOE's Low-Temperature program focused on replacing part of GEOTHERM by building a new database primarily of low- and moderate-temperature geothermal sources for use on personal computers. For Utah, building this new database involved: (1) identifying sources of geothermal data; (2) designing a database structure; (3) entering the new data; (4) checking for errors, inconsistencies, and duplicate records; (5) organizing the data into reporting formats; and (6) generating resource maps of Utah showing the



Distribution of thermal wells, principal geothermal areas, and physiographic provinces in Utah.

locations and record-identification numbers of thermal wells and springs.

Geothermal Areas

Low energy costs in Utah have contributed to the relative slow growth of geothermal energy usage in the state. Presently, electric power is generated at the Roosevelt Hot Springs KGRA (26 megawatts) and at the Cove Fort - Sulphurdale KGRA (13 megawatts) in Beaver County. Commercial greenhouses that use thermal water for space heat operate at Newcastle in Iron County, and at Crystal Hot Springs near Bluffdale in Salt Lake County. Several commercial resorts use geothermal water for heating swimming pools, small space-heating applications, and therapeutic baths. One of the newer developments using low-temperature geothermal water directly is a commercial scuba-diving and aquaculture facility near Grantsville in Tooele County. A similar development is in northern Box Elder County. Many undeveloped thermal springs are used informally by recreational enthusiasts for therapeutic bathing.

Utah encompasses parts of three major physiographic provinces — the Colorado Plateau, the Middle Rocky Mountains, and the Basin and Range Province — each with characteristic landforms and geology. The Basin and Range - Colorado Plateau Transition Zone (the "Transition Zone") extends through central and southwestern Utah, and contains physiographic and geologic features of both the Basin and Range and Colorado Plateau provinces. The higher temperature, larger geothermal systems in Utah are clustered in the Basin and Range and Transition Zone, they exhibit high heat-flow relative to the other provinces. The worldwide average conductive heat flow to the earth's surface is about 61 milliwatts per square meter (mWm^{-2}) for the continents. Typical values for heat flow in the Basin and Range Province vary between 80 and 120 mWm^{-2}. The Colorado Plateau and the Mid-

Continued on page 15 . . .

Principal geothermal springs (S), wells (W), and areas (A) inUtah.

NO.	NAME	TYPE	DISCHARGE TEMP, °C	ESTIMATED FLOW, L/min	RESERVOIR TEMP, °C	DEPTH, m	DEVELOPMENT
1	Uddy, Belmont	S	53	6,000	55-90	—	resort
2	Crystal Madsen	S	56	3,600	60-90	—	resort
3	Little Mtn.	S	42	1,700	50-80	—	none
4	Stinking	S	48	100	70-90	—	none
5	Chesapeak	W	74	150	70-80	153	unknown
6	Utah	S	58	121	70-100	—	greenhouses
7	Ogden	S	58	20	70-100	—	none
8	Hooper	S	60	—	80-120	—	unknown
9	Becks	S	55	—	60-100	—	none
10	Wasatch	S	42	240	50-90	—	none
11	Crystal Bluffdale	A	58	—	90-120	—	greenhouses
12	Midway	A	45	180	70-75	—	resort
13	Saratoga	S	44	700	60-100	—	resort
14	Castilla	S	40	—	50-90	—	none
15	Third Water	S	55	—	65-100	—	none
16	Goshen Valley	S	61	—	60-70	—	none
17	Bonneville DBW 3	W	88	—	—	630	unknown
18	Blue Lake	S	29	—	50-90	—	none
19	Wilson Health	S	55	—	55-100	—	none
20	Abraham, Crater	S	85	1,200	100-150	—	none
21	Neels RR	W	HOT	—	200 (?)	610	abandoned
22	Meadow-Hatton	S	63	20	70-120	—	none
23	Monroe-Red Hill	A	82	540	90-120	—	resort
24	Joseph	S	63	120	90-150	—	none
25	Cove Fort	A	150	—	180-225	370	electric power
26	Roosevelt	A	240	—	260-290	2,590	electric power
27	Thermo	A	90	40-70	140-200	—	none
28	Wood's Ranch	W	37	—	110-120	60	none
29	De Armand	W	149	3,785	—	3,750	unknown
30	Newcastle	A	97	—	140-170	150	greenhouses
31	Veyo	S	30	390	40-60	—	resort
32	Dixie,Pah Tempe	S	42	18,000	50-90	—	resort
33	Split Mountain	S	30	10,200	—	—	none
34	Ashley Valley	W	58	—	—	1,710	none

Energy News

Welcome to the 90s!
Is Tar Sand Development Part of Our Future?

by Roger L. Bon and Charles E. Bishop

What a difference a decade makes. It has been almost 10 years since the last of several attempts to produce oil from the tar sands at Asphalt Ridge near Vernal, Utah. The only activity since that time has been mining the tar sand for road repair and paving material. The problem is not availability, but the cost of methods to extract the hydrocarbon. The outlook may have improved recently, however, with the development of a new project at Asphalt Ridge. Buena Ventura Resources, a subsidiary of Crown Energy Corporation, completed testing of a 100 ton-per-hour demonstration plant for hydrocarbon extraction in June 1994. This superseded a smaller pilot plant which operated successfully in 1992.

In December 1994, Crown Energy announced permitting of a commercial facility which will produce 3,000 to 4,000 barrels of oil per day at an estimated cost of $9.00 per barrel. The projected rise in oil prices should have a positive effect on the viability of this long-awaited development. Advancements involving the recovery of this vast, non-conventional energy resource will be of significant benefit to the local and state economy.

Asphalt Ridge is 15 miles long, trends northwest, and is located three miles west of Vernal, Utah. Its naturally occurring asphalt has an oil content of up to 25% by volume and 14% by weight, and resource estimates exceed one billion barrels of oil. This tar-sand deposit is one of the largest of the 27 known deposits in the Uinta basin, which range in size from less than one million to over three billion barrels of in-place oil. Asphalt Ridge is also the most accessible of Utah's large tar-sand deposits. Tar sands are contained within two sandstone-siltstone strata exposed for about 12 miles along the ridge. These strata are in the Tertiary Duchesne River Formation, which is currently being mined, and the underlying Cretaceous Rimrock Sandstone Member of the Mesaverde Group.

Buena Ventura Resources demonstration plant.

The oil-bearing part of the Duchesne River Formation varies from 0-300 feet thick, whereas the Rimrock Sandstone varies from zero to approximately 100 feet. The two asphalt-bearing zones are commonly separated by as much as 200 feet of barren rock. Some of the oil-bearing deposit is near the surface where it is easily recovered with surface-mining equipment, but most is deeply buried and will require alternative recovery techniques.

Buena Ventura Resources began testing their patented cold separation process for removal of oil in 1992. The process involves mixing raw tar sand with a diluent to soften and separate the oil from the sand, then mixing with water to separate the sand from the oil-diluent mixture. The water is filtered and recycled for further use. The sand is subsequently separated from the mixture, cleaned, and disposed of. The sand waste is reported to be 99.6% oil free with a moisture content of 10 to 15%. The oil-diluent mixture was sent to a refinery in Salt Lake City for testing and analysis; one ton of raw material yields about 1/2 barrel of oil; the quality is ideally suited for processing into an asphalt product or into numerous petroleum- based products including gasoline.

Utah's 1994 Coalbed Gas Developments

by David E. Tabet

Significant coalbed gas development is occurring in central Utah that could eventually lead this new gas source to account for more than 25 percent of the state's production. Although a few coalbed gas tests were made in the 1980s, significant interest blossomed in the 1990s with six companies involved. This article summarizes the publicly announced exploration, production, and leasing activities of these companies (in alphabetical order) during 1994.

Exploration for natural gas associated with coal beds began in the late 1970s in New Mexico and Alabama, and has only recently expanded to include some areas in central Utah. Coalbed gas forms during the process of coalification and, unlike the gas in conventional reservoirs, it is trapped in the molecular pores in the coal. The gas is produced by reducing the hydrostatic pressure by pumping off the water contained in the coalbed. Disposal of the water produced with the gas can be a problem in some fields. Coalbed gas accounted for two percent of the U.S. natural gas production in 1991 and has been increasing steadily.

Anadarko Petroleum Corporation continues testing the gas-production capability of Cretaceous coals in various parts of the Book Cliffs and Emery coal fields. Anadarko staked a new test well, the Matts Summit Federal 12-A1, to the west of the Castlegate field in the western portion of the Book Cliffs coal field. This well will be drilled to a depth of 5,800 feet to test Blackhawk Formation coals and sandstones. In January 1994, Anadarko purchased a lease for 475 acres of federal land in sections 24 and 25, T. 11 S., R. 8 E. (Salt Lake Baseline), at the west end of the Book Cliffs coal field. Anadarko's biggest move was the purchase, effective August 1, 1994, of PG&E Resources' interest in the Castlegate coalbed gas field. That transaction included PG&E's 16,300 net acres of leases and 26 coalbed gas and disposal wells.

In the Emery coal field, Anadarko continued development drilling north of Price near two successful wells completed during late 1993, the A-1 and B-1 Helper. These two wells produced 10 and 3 million cubic feet of gas respectively during testing of the Ferron Sandstone Member of the Mancos Shale before being shut in. During the summer of 1994, the U.S. Bureau of Land Management (BLM) completed an Environmental Assessment to permit Anadarko to drill four new wells on leases covering parts of five sections in T. 13 and 14 S., R. 10 E. In November 1993, Anadarko was the successful bidder on a 1,387-acre federal oil and gas lease tract that lies to the southwest of River Gas Corporation's current Drunkards Wash project area. No new drill holes are staked on this acreage. In April 1994, Anadarko was the winner at a state lease sale for an 80-acre tract to the northeast of the Drunkards Wash gas field, near Price, Utah.

At the southern end of the Emery coal field, about three miles west of Emery, Utah, Anadarko completed the A-1 Ferron-Federal to test Ferron Sandstone coals. Cores were taken from 2,496 feet to 3,008 feet, but the well was abandoned in March 1994 and no test results have been released to date.

Cockrell Oil Corporation was the initial discoverer of the Castlegate gas field north of Price, Utah. However, since selling its interest in that field to PG&E Resources in 1993, the company has not conducted any new exploration nor has it announced any new plans for future coalbed-gas tests in Utah. The company did purchase 1,900 acres of new federal oil and gas leases in the southwest quarter of T. 12 S., R. 9 E.

EFG&E, Incorporated, a corporation based in Price, Utah, has filed notices of staking with the BLM for three wildcat wells near the Carbon-Emery County line. The objective of these wells was not disclosed, but the wells are located within the River Gas coalbed methane Environmental Impact Statement (EIS) study area, and likely will test Ferron Sandstone coals. No activity has occurred at the Scorpion 1-23, Capricorn 1-27, and Pegasus 2-27 sites as of the end of 1994.

As of the end of 1993, all 25 **PG&E Resources Company** wells were completed and the major construction of the gas distribution and processing facilities for the Castlegate coalbed gas field had been completed. The wells, shut in during construction of the processing facilities, were brought back into production in March 1994. Production from 24 wells during March totaled 32,259 thousand cubic feet (Mcf) of gas and 212,708 barrels (bbl) of water. During the months from April through July gas production from the 24 wells increased steadily from 36,962 Mcf to 52,509 Mcf. Meanwhile, water production from the wells decreased from 176,392 bbl in April to 150,902 bbl in July. The average daily production per well in the Castlegate gas field during July was 73 Mcf of gas and 240 bbl of water; daily well production ranged from 4 to 170 Mcf of gas, and 0 to 590 bbl of water. PG&E sold its interest in the Castlegate gas field to Anadarko.

Since late 1992, **River Gas Corporation** of Utah has maintained a steadily growing coalbed-gas development program in the Cretaceous Ferron Sandstone coals to the west and south of Price. The program began with the drilling and completion of five wells in late 1992. During 1993, the newly designated Drunkards Wash gas field was gradually expanded by 28 additional wells (total 33). These 33 wells, brought into production at varying times, produced 856,600 Mcf of gas and 1,608,703 bbl of water during 1993. Their monthly gas production in December of 1993 was 155,945 Mcf. River Gas completed two wells outside of the Drunkards Wash unit in January 1994, but neither was brought into production. Continued dewatering of the 33 producing wells in the Drunkards Wash field increased monthly gas production for April 1994 to 328,437 Mcf, and gas production has remained consistently above 300,000 Mcf per month through September 1994.

Development drilling by River Gas in the southern part of the Drunkards Wash field began in July 1994 and, through November, two rigs had completed 34 new wells. Six more wells are planned with a 160-acre well spacing. In addition, River Gas also became the operator in May 1994 of three wells previously drilled by Texaco in the Drunkards Wash area: Pinnacle Peak Unit 2, E.G. Telonis #1, and Government-W.A. Drew #2, all located in T. 14 S., R. 9 E. Thus, by the end of 1994 River Gas should have a total of 85 wells in the Drunkards Wash field. Two new drill sites were announced in September on state and private lands, but were not drilled in 1994.

River Gas has continued expanding its lease holdings along the Ferron Sandstone coal trend. At the November 1993 BLM lease sale, it had the winning bid for three new federal tracts in Emery County. These tracts cover roughly 6,638 acres in parts of T. 16 S., R. 8 and 9 E. River Gas also purchased leases for approximately 10,039 more acres of state and federal land during sales in early 1994. This new acreage is scattered over parts of six townships in southwestern Carbon County and northwestern Emery County, and lies west and south of the currently producing Drunkards Wash field.

August 1994 marked an announcement by the BLM that an EIS covering a 10-township area is being prepared to address the impacts of River Gas' plan to drill as many as 1,000 new coalbed-gas wells near Price. According to the announcement, River Gas might drill 100 new wells in 1995 plus 100 new wells each year for the following nine years. River Gas' drilling to date has been confined to state and private lands, and completion of the EIS is required to permit drilling to extend onto adjacent federal lands.

Texaco Exploration and Production, Inc., an early wildcat driller in the Price area, and more recently a partner with River Gas on the Drunkards Wash field development, has renewed its individual exploration efforts to test coalbed gas reservoirs of the Ferron Sandstone. In late 1994, Texaco staked three wells to test Ferron coals in western Emery County. The first well, the 10-1 M. Lemmon, is about 15 miles southwest of the River Gas/Texaco Drunkards Wash project, and about two miles west of Huntington, Utah. The second well, the 26-2 Federal, lies about nine miles farther southwest, about two miles west of Castle Dale, Utah. Drilling on this well was completed during late November 1994. The third well, the 21-3 Federal, is staked about three miles due north of the town of Ferron, Utah.

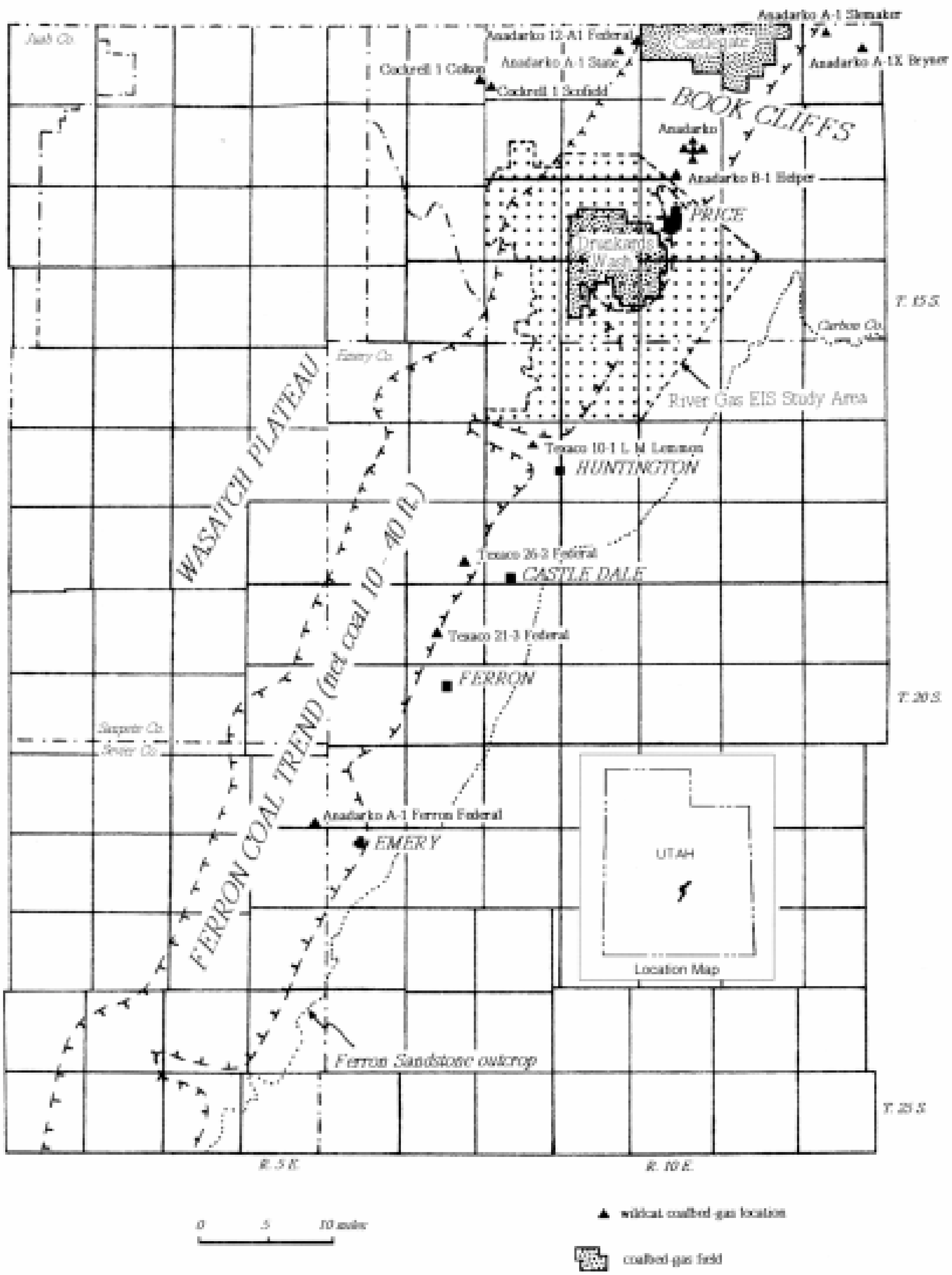
Summary

PG&E Resources Company and River Gas of Utah have developed two new coalbed-gas fields in Utah in the past few years. Further development activity at the Castlegate

MONTH/YR	NUMBER OF WELLS	GAS(Mcf)	WATER(bbl)	AVERAGE DAYS/WELL	AVERAGE GAS/WELL/DAY
09/93	17	81,291	201,399	27	177 MCF
10/93	19	97,543	261,372	28	183 MCF
11/93	25	117,260	246,288	27	174 MCF
12/93	32	155,945	282,196	26	187 MCF
01/94	33	212,012	286,774	30	214 MCF
02/94	33	207,979	213,082	22	286 MCF
03/94	33	291,654	309,787	30	294 MCF
04/94	33	328,437	312,686	30	332 MCF
05/94	33	328,166	256,959	30	331 MCF
06/94	32	303,962	205,778	28	339 MCF
07/94	33	323,716	219,106	29	338 MCF
08/94	33	319,897	197,553	30	323 MCF
09/94	33	335,428	135,233	30	339 MCF

Monthly Production Statistics for the Drunkards Wash Field (data from the Utah Division of Oil, Gas, and Mining).

field may resume with the recent transfer of ownership to Anadarko Petroleum. River Gas' proposed level of development at the Drunkards Wash field alone would make Utah a major coalbed-gas-producing state, and may possibly make this gas field one of the largest in the state. Assuming that the 33-well monthly production rate of 330,000 Mcf of gas can be extrapolated upward for the proposed 1,000-well development scenario, the results would be an estimated ultimate monthly gas production rate for the Drunkards Wash area of 10,000,000 Mcf. On an annual basis this field could produce 120,000,000 Mcf. This compares with the total 1993 statewide production of natural gas of 336,603,380 Mcf. Other promising areas farther south along the Ferron Sandstone trend are just starting to be explored by Anadarko, EFG&E, and Texaco. Successful exploration in these new areas could lead to even greater Utah coalbed gas production. ■



Coalbed-gas activities in central Utah

Exploration Begins for Precambrian Oil in Utah

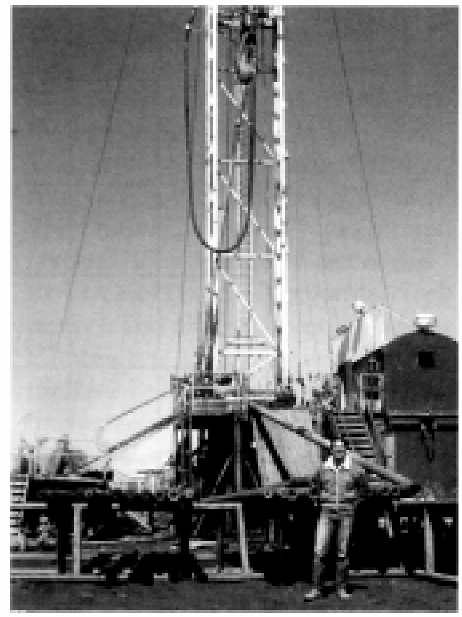
by Thomas C. Chidsey, Jr.

In 1990, the Utah Geological Survey and the U.S. Geological Survey presented results of a study indicating that mudstones and siltstones of the Precambrian (late Proterozoic) Chuar Group in the Grand Canyon, Arizona are potential petroleum source rocks. Geochemical analyses showed that these rocks are organic rich, probably containing as much as 10% organic carbon, and are within the oil-generating window. Preliminary evaluations suggested that the Chuar or equivalent units underlie some areas of the Colorado Plateau in Utah, representing a significant hydrocarbon potential for the region. Exploration targets include the basal Cambrian Tapeats Sandstone and other lower Paleozoic reservoir rocks as well as Precambrian rocks. Four years later, the first exploratory drilling based on this work has begun with two wells drilled and a third planned.

On the Paria Plateau in southern Kane County, Burnett Oil Company drilled the 1-36 Kaibab well (SW1/4 NE1/4 section 36, T. 43 S., R. 3 W.) to a depth of 5,362 feet. The Precambrian was penetrated at 4,780 feet after which 585 feet of Chuar (?) sedimentary rocks were drilled. The well was plugged with no significant shows.

On the Circle Cliffs uplift in Garfield County, BHP Petroleum drilled the 1-28 Federal well (SW1/4SE1/4 section 28, T. 33 S., R. 7 E.) to a depth of 6,185 feet. The penetrated Precambrian section consisted of schist; no sedimentary rocks were encountered. The well was plugged and abandoned after testing flows of carbon dioxide in the Paleozoic section.

In the Kaiparowits basin in southern Kane County, Rangeland Exploration Company plans to re-enter the Union Oil Company 1 Judd Hollow Unit well (SW1/4NW1/4 section 19, T. 43 S., R. 2 E.). The Judd Hollow well was drilled in 1966 to a depth of 7,341 feet in the Cambrian. Rangeland will deepen the original well to 9,350 feet, testing a significant part of the Precambrian section. ■



Burnett Oil Company's 1-36 Kaibab well. Photo courtesy David Allin.

Coming Soon - Resistivities and Chemical Analyses of Selected Oil Fields and Other Waters, Utah

by J. Wallace Gwynn

The Utah Geological Survey (UGS) is publishing a report on the electrical resistivities and chemical analyses of selected oil field and other waters from throughout the state. This report presents about 2,300 analyses of subsurface water samples from shallow water wells, springs, and from oil and gas exploratory and development wells. It provides essential information to the oil industry to be used during drilling, testing, and evaluating oil and gas wells. In addition, water resistivities can be used in planning the appropriate disposal of saline water often co-produced with the oil.

The geologic age of the host aquifers and reservoirs of these waters range from Devonian through Tertiary. Water samples from the shallow wells and springs are from various local, intermediate, and regional ground-water flow systems. Samples from oil and gas wells are from specific stratigraphic horizons or individual geologic formations from most of the major oil and gas reservoirs and fields in Utah.

The chemical analyses in this report contain values for the ions Na^{+1}, Mg^{+2}, Ca^{+2}, Cl^{-1}, SO_4^{-2}, HCO_3^{-1}, and in many cases K^{+1} and CO_3^{-2}. The total dissolved solids are calculated as the sum of the major ions, including K^{+1} and CO_3^{-2}. Although water resistivity (Rw) values can be determined from certain types of geophysical logs, atypical drilling problems in Utah make such data suspect. The Rw values in this report are the preferred, direct measurements from water samples or are derived from the chemical analyses. ■

Utah Quartzite Building Stone

Greatest Stone on Earth

by Bryce T. Tripp

An examination of Salt Lake architecture reveals abundant use of white, silver, grey, green, and gold quartzite flagstone and ashlar (brick-shaped stone set in horizontal layers) for building veneer. The Boy Scouts of America Building (525 South Foothill Drive) is an attractive example of the use of quartzite flagstone veneer. Several stone companies produce sizable quantities of quartzite from the Raft River and Grouse Creek Mountains of northwestern Utah. The stone comes from the metamorphosed Precambrian Elba Quartzite (a micaceous quartzite) and the Cambrian (?) Quartzite of Clarks Basin (a mica quartz schist).

The quartzite commands a premium price on the building stone market due to the following desirable characteristics: (1) it splits into large, thin sheets that are relatively inexpensive to ship and easy to install, (2) it is durable due to its strength, hardness, and impermeability, and (3) it occurs in a range of colors with varying degrees of micaceous surface sheen and decorative iron staining.

A few, small stone companies began producing this stone in the mid-1950s. The industry has since grown into a sophisticated nationwide business. A resurgence in interest in natural stone in buildings, an increase in building construction starts, and aggressive marketing by stone companies have increased the production markedly in the last few years. Stone companies have also begun promoting this thinly cleft quartzite for formal architectural use. Sawing the quartzite into uniform tiles allows it to compete in the large markets for formal granite, marble, and ceramic-tile flooring and wall veneer.

Details of the geology of the quartzite deposits and a description of the quartzite stone industry are contained in the recently published Utah Geological Survey Special Study 84. This publication includes color photographs and is available from the UGS for $5.00. ■

Core Workshops

by Carolyn M. Olsen

Five technical workshops were held at the UGS Sample Library last May and September to study five Ferron Sandstone cores drilled in Emery County, Utah by BP Exploration (Alaska), Inc. The Ferron's depositional environment is analogous to the lower part (zone 1) of Alaska's Ivishak Formation, the reservoir rock of Prudhoe Bay, which contains approximately two billion barrels of oil reserves at an approximate depth of 9,000 feet. However, the Ivishak has no suitable outcrops which can be studied to understand this type of reservoir rock, whereas the Ferron has excellent outcrop exposure. Similarities between the Ferron and Ivishak include stratigraphy, facies distribution, and lithology. The British Petroleum (BP) geologists studied the Ferron to help predict inter-well distribution of rock types and their porosity and permeability in the Prudhoe Bay and other similar fields.

The 1994 workshop was the third BP has held at the Sample Library and was attended by 20 BP and Arco geologists under the direction of Gus Gustason and Buster Bryant.

British Petroleum geologists study the Ferron Sandstone core at a training workshop at the Utah Geological Survey Sample Library.

Four other Ferron workshops, also held in 1994, were attended by: (1) 36 Mobil Oil Corporation geologists led by Richard Moiola; (2) five Texaco geologists led by Tom Ryer of Aries Group, Inc.; (3) 15 students from the University of Utah led by their instructor Marjorie A. Chan; and (4) seven Brigham Young University (BYU) students led by Dr. Thomas Morris. The BYU students also studied core from the Bluebell field in Uintah County.

Ward Abbott of Occidental Oil and Gas Corporation accompanied seven geoscientists visiting from China who wanted to see an American sample library. They viewed a variety of different cores and discussed the various aspects of the Sample Library through an interpreter. ■

Teacher's Corner

by Sandy Eldredge

Global Quest

Join the information superhighway. A 12-minute video, "Global Quest: The Internet in the Classroom," shows teachers how to use Internet to help with classroom teaching. The video is $15.00 plus shipping. For more information, contact NASA Resources for Educators, Lorain County Joint Vocational School, 15181 Route 58 South, Oberlin, Ohio 44074, (216) 774-1051, ext. 293 or 294.

Seismo-Surfing the Internet

Those of you teaching about earthquakes will be interested to know that you can now obtain Utah-specific information through Internet thanks to free software called Mosaic and the University of Utah Seismograph Stations. Mosaic allows easy access to information such as: questions and answers about Utah-specific earthquake concerns as well as general earthquake information; lists of the time, location, and magnitude of the 25 most recent earthquakes in the Utah region; maps of faults in the Intermountain West and in four Wasatch Front counties; and where to call for more information about earthquakes, faulting, and preparedness in Utah. The Internet address, or command to use, is: http://www.seis.utah.edu

Seismic-Sleuthing

Speaking of earthquakes...... the Utah Geological Survey is participating with the University of Utah Seismograph Stations (UUSS), the University of Utah departments of Geography and Geology/Geophysics, and the Utah Division of Comprehensive Emergency Management to develop Utah-specific earthquake curricula. "Content specialists" from these institutions will work with several Utah teachers in designing materials and training to meet the needs of third, fifth, and eventually ninth-grade teachers in implementing the new state science core curriculum. Three third-grade teachers, three fifth-grade teachers, and one ninth-grade teacher will work with the content specialists on this winter-spring, 1995, project. We will keep you posted.

Recent Publications of Interest

(Not available from UGS)

Maps summarizing geohydrologic information in an area of salt-water disposal, eastern Altamont-Bluebell petroleum field, Uinta Basin, Utah by G.W. Freethey, 1994, USGS WRI-92-4043

Hydrogeology of the L.C. Holding coal-lease tract and adjacent areas, southwestern Utah, and potential effects of coal mining, by G.E. Cordy, R.L. Seiler, and B.J. Stolp, 1993, USGS WRI-91- 4111

Landslide deposits in the Grouse Creek 30′ x 60′ Quadrangle, Utah, Nevada, and Idaho, by R.B. Colton, 1994, USGS OF-91-298

Tectonic trends of the northern part of the Paradox Basin, southeastern Utah and southwestern Colorado, as derived from Landsat multispectral scanner imaging and geophysical and geological mapping, by J.D. Friedman, J.D. Case, and S.L. Simpson, 1994, USGS B-2000C Uncontrolled X-band radar mosaic of the western part of the Moab 1 x 2 degree quadrangle, southeastern Utah and southwestern Colorado, by J.D. Friedman and J.S. Heller, 1994, USGS B-2-000D

Dolomite and siliciclastic dikes and sills in marginal-marine Cretaceous coals of central Utah, by J.K. Hardie, 1994, USGS B- 2087A

Geohydrology and water chemistry of abandoned uranium mines and radiochemistry of spoil-material leachate, Monument Valley and Cameron areas, Arizona and Utah, by S.A. Longsworth, 1993, USGS WRI-93-4226

Geological, geochemical, and geophysical studies for the Goshute Reservation, Nevada and Utah, precious-mineral assessment project, by C.J. Nutt and others, 1992, USBIA Report 92-2

Oil and gas resources of the U.S. Naval Oil Shale Reserves 1 and 3, Colorado, and Reserve 2, Utah, by T.D. Fouch and others, 1994, USGS OFR-94-0426

Major-element, trace-element, and volatile concentrations in silicate melt inclusions of the tuff of Pine Grove, Wah Wah Mountains, Utah, by J.B. Lowenstern and others, 1994, USGS OFR- 94-0242

The Rockhounder

Topaz at Topaz Mountain, Juab County

By Christine M. Wilkerson

THE ROCKHOUNDER is a regularly appearing column in Survey Notes. In each issue, a member of the Geologic Extension Service will highlight an interesting Utah rock or mineral, and provide information on where and how to collect it.

Geologic information: Topaz, Utah's state gem, is a semiprecious gemstone that occurs as very hard, transparent crystals in a variety of colors. The topaz crystals at Topaz Mountain are naturally amber colored, but become colorless after exposure to sunlight. The crystals formed within cavities of the Topaz Mountain Rhyolite, a volcanic rock which erupted approximately six to seven million years ago (Tertiary Period) from volcanic vents along faults in the area.

How to get there: From Nephi, Utah, travel 33 miles southwest on State Highway 132 to Lynndyl. Turn south on U.S. Highway 6 and drive for approximately 5 miles (if coming from Delta, travel 11 miles north on U.S. Highway 6). Turn west on the Brush Wellman road and travel 38 miles until you reach the Topaz Mountain sign. Turn north on the dirt road and drive about 2 miles, then turn west toward Topaz Mountain. Much of this area is on a section of School Trust Land (state land); please see land ownership and collecting rules below.

Where to collect: Single colorless topaz crystals can be found in the washes around Topaz Mountain. Crystals are usually less than an inch long. Larger amber crystals or clusters of topaz can be found by breaking open the white rhyolite to find cavities.

Useful maps: Utah highway map, Lynndyl and Fish Springs 1:100,000-scale topographic maps, Topaz Mountain East 7.5-minute topographic map, and the Bureau of Land Management (BLM) Recreation and Vehicle Guide to the House Range Resource Area map. Topographic maps can be obtained from the Utah Geological Survey, 2363 South Foothill Drive, Salt Lake City, (801) 467-0401. BLM maps are available from the BLM Utah Office at 324 South State, Salt Lake City, (801) 539-4001.

Topaz crystals from the Topaz Mountain area. These crystals vary in length but are each less than 1 inch long.

Land ownership: BLM public lands, School Trust Land (state land) on section 16 of Township (T.) 13 S., Range (R.) 11 W., and private gemstone lease located in the northwest 1/4 of the northwest 1/4 (NW1/4NW1/4) of section 16, T. 13 S., R. 11 W.

Precautions, miscellaneous: A four-wheel-drive vehicle is recommended but not required for the last few miles of the journey. Do not collect on marked claims. Bring a rock hammer and protective eyewear if you intend to break pieces of rock. A hat and water are recommended. Watch for rattlesnakes. Please carry out your trash. Have fun collecting!

BLM collecting rules: The casual rockhound or collector may take small amounts of petrified wood, fossils, gemstones, and rocks from unrestricted federal lands in Utah without obtaining a special permit if collection is for personal, non-commercial purposes. Collection in large quantities or for commercial purposes requires a permit, lease, or license from the BLM.

School Trust Land collecting rules: State-owned properties are managed by the School and Institutional Trust Lands Administration and a rockhounding permit is required to collect on these lands. The annual permit costs $5.00 for individuals or a family, and $200.00 for an association/organization. With the permit, rockhounds may collect up to 25 pounds plus one piece per person per day, up to a maximum of 250 pounds per year. Commercial collectors must apply to the Trust Lands Administration for mineral leases. To obtain a rockhounding permit, please contact Teresa Wilhelmsen, School and Institutional Trust Lands Administration, 355 West North Temple, 3 Triad Center, Suite 400, Salt Lake City, (801) 538-5508.

"Glad You Asked"

by Rebecca Hylland

We often receive questions about **UTAH'S STATE SYMBOLS**, especially those that concern the state mineral (copper), rock (coal), and gem (topaz). Most of these inquiries are from people who live outside the state and are planning Utah rock- and mineral-collecting vacations.

Minerals are naturally occurring inorganic elements or compounds that have an ordered internal structure and characteristic chemical composition, crystal form, and physical properties. For example, quartz is a mineral as is copper. Minerals combine to form rocks like granite, basalt, and sandstone. Rocks can also be composed of solid organic matter, coal is an example. Gems are especially fine ("gem quality") mineral specimens that have few flaws in their internal structure and exhibit superior color. Typically these high-quality minerals are cut and used in jewelry.

Utah's state mineral, copper, is versatile and widely used mainly for its conductive properties (heat and electricity). It is used in electronics, plumbing, transportation, and in alloys (a mixture of two or more metals). Most of the copper mined in Utah comes from Kennecott's Bingham Canyon mine in the Oquirrh Mountains on the west side of the Salt Lake Valley. The Bingham Canyon mine is the world's largest open-pit copper mine, measuring 0.5 miles deep and 2.5 miles wide. For perspective, the world's tallest building, the Sears Tower, is 1,454 feet tall and would reach only halfway up the side of the pit. The mine has produced 12 million tons of copper since open-pit operations began in 1906. This production figure is eight times the total metallic mineral yield from the Comstock Lode, Klondike, and California gold rushes combined. The Bingham Canyon mine is an important contributor to Utah's economy.

Coal, Utah's state rock, originates as plant matter that accumulates in wetlands and bogs. Coal begins to form when anaerobic bacteria break down plant material and convert it to peat through the removal of oxygen and hydrogen. The peat is then buried by sediment and more plant material, raising the temperature and pressure of the peat. As the peat compresses, water and methane gas are forced out, leaving an increasing proportion of carbon. With increasing heat and pressure the peat is converted successively into lignite, subbituminous coal, bituminous coal, and anthracite. Most of the coal mined in Utah is bituminous.

Coal is used during the coking process in steel production, and is burned in power plants to produce heat and electricity. Over one-half of the electricity used in Utah is generated by coal-burning facilities. Coal is found in 17 of Utah's 29 counties, but coal mining is primarily concentrated in Emery and Carbon Counties. Coal production in Utah during 1994 is estimated at 24 million tons.

Topaz, Utah's state gem, occurs in cavities in the rhyolites of the Thomas Range of western Utah, and is found in a variety of colors (for example, pink, violet, yellow, green, blue) or may be colorless. Due to its durability and beauty, topaz is used primarily in jewelry. For information on where to collect topaz in Utah, refer to "The Rockhounder, Topaz at Topaz Mountain" article in this issue.

Other state symbols include:

- FOSSIL: The *Allosaurus*, a species of carnivorous dinosaur, roamed the Utah region about 160 million years ago. More *Allosaurus* specimens have been found in Utah's quarries than any other dinosaur. On average, the Allosaurus weighed four tons, stood 17 feet high on two legs, and measured 35 feet long.
- TREE: The blue spruce (*Picea pungens*) is a variety of evergreen tree capable of withstanding temperature extremes found in the Wasatch Range and Uinta Mountains at elevations from 6,000 to 11,000 feet. In Utah it is used as an ornamental tree.
- GRASS: Indian ricegrass (*Oryzopsis hymenoides* Ricker) isa native perennial bunchgrass used as a food staple by the indigenous peoples of Utah. Indian ricegrass seed can be ground into meal or flour and made into bread.
- ANIMAL: Rocky Mountain elk (*Cervus canadensis*) are related to deer and moose and live in most of the mountain ranges of Utah. Mature bulls can weigh up to 700 pounds.
- FLOWER: The sego lily (*Calochortus nuttallii*) grows 6 to 8 inches high and is found in the grasslands of the Basin and Range Province. During their first winter in Utah, the pioneers supplemented their diet with sego lily corms because food was scarce.
- BIRD: The California gull (*Larus californius* Lawrence) saved the crops of the early pioneers from crickets in 1848 and 1849. It nests in large colonies on the islands and dikes in the Great Salt Lake and Utah Lake, and can be seen along Utah's waterways.
- FISH: Rainbow trout (*Salmo gairdneri* Richardson) are Utah's most popular sport fish. They live in cold-water lakes and streams.
- INSECT: In Utah, the honey bee (*Apis mellifera*) is considered the symbol of industry.

For more information on Utah's state symbols contact the Utah Travel Council at (801) 538-1030. ■

. . . Director's Perspective continued

demonstrate technical and economic success, this technique could be applied to more than 75 similar fields in the area leading to the recovery of up to 200 million additional barrels of oil.

The UGS also has been working with Summit County officials to interest the petroleum industry in taking a new look at opportunities in the "thrust belt" centered in the county. A few years ago the UGS identified and promoted oil and gas reservoirs in some of the thrust belt fields as excellent candidates for horizontal drilling techniques whereby the drill bit is gradually deflected during drilling to follow oil-rich geologic layers. In the past year, Union Pacific Resources drilled three very successful horizontal wells in the Pineview field, to drain undeveloped horizons.

The results of these and other projects are continually being shared with the petroleum industry through technical presentations at scientific and professional meetings nationwide. In addition, the UGS is "marketing" Utah opportunities through exhibits at trade and technical meetings. Does it work? Well, for the past three years we have tracked industry activity in Utah. In 1993 we saw 34 new companies start operating in Utah that were not here in 1992. This includes exploration programs, drilling wells, and opening Utah offices. In 1994 another 20 companies began working in Utah. In a recent "Oil Reporter" magazine article on activity nationwide, Utah was singled out for its aggressive campaign to attract new interest and investment to the state.

The UGS role in trying to turn around the oil industry is unique among all the states, but it's a mission we think worthwhile and achievable. ■

Geothermal

. . . continued from page 5

dle Rocky Mountains provinces have heat-flow values near the worldwide average.

Locations and general information on selected geothermal areas in Utah are shown on the map and listed below. In central and western Utah, most geothermal systems are located in valleys near the margins of mountain blocks, and are thought to be controlled by active basin-and-range faults. Other geothermal systems occur in hydrologic discharge zones at the bottoms of valleys, and a few thermal areas are located in mountainous regions.

Known high-temperature systems, with reservoir temperatures above 150°C (302°F), are the Roosevelt Hot Springs and Cove Fort - Sulphurdale KGRAs. Based on geological and geochemical evidence, four other areas in Utah have been suggested as possible high- temperature geothermal systems. These include Thermo Hot Springs, Joseph Hot Springs, the Newcastle area, and the Monroe-Red Hill area. Ten other areas could be classified as moderate-temperature geothermal systems with reservoir temperatures between 90°C and 150°C (194°F and 302°F). High-temperature systems are generally considered capable of producing economical electric power. Moderate-temperature systems are often used for space-heating of buildings and greenhouses, in industrial processes, and sometimes for binary electric-power generation. Low-temperature systems, with temperatures less than 90°C (194°F), are also used for space-heating (including geothermal heat-pumps) and in agricultural applications.

Data Sources

The data used in this project were derived from the more than 40 geothermal-related projects in Utah that DOE, the USGS, the National Science Foundation, and the UGS either funded or co-funded over the past 20 years. Many reports from these projects included geochemical and other data on wells and springs. Basic data on geothermal waters in Utah are included in these reports as well as in journal papers, water-resource databases, and so forth. An additional source of information was the USGS's on-line water-information system known as the National Water Data Storage and Retrieval System, or WATSTORE. It is composed of various files and databases containing continually updated records on monitored wells and springs in the United States.

Database Format and Contents

A database format comprising three general divisions (location information, descriptive information, and water chemistry) was developed using commercial database-management software. Data from published sources on wells and springs were entered manually and were checked against the original data for accuracy. Sorting routines were used to help identify and eliminate duplicate records. After manual entry of 380 records, all of the data were exported to a spreadsheet program for ease of editing and for combining with 1,100 digital WATSTORE records provided by the USGS Water Resources Division. After eliminating duplicate and ambiguous records, the finished database consists of 964 records for 792 well and spring locations with temperatures of 20°C (68°F) or more. The database is available in both hard-copy and digital formats.

Distribution of Geothermal Sources

Because of the large number of records that needed to be presented, two resource maps were compiled. Plate one of UGS Open- File Report 311 is a 1:750,000-scale map of the state showing the locations of all records and the map numbers for those records with temperatures of 25°C (77°F) or more. Plate 2 shows the locations and map numbers for those records with temperatures between 20°C and 25°C (68°F and 77°F). The distribution of geothermal sources plotted from the new database is similar to that of the 1980 resource map. The majority of thermal wells and springs are located along the eastern margin of the Basin and Range Province or within the Transition Zone. Thermal systems in the lower temperature ranges are much more abundant than those in the higher temperature ranges. ■

New Publications of the UGS

Low-temperature geothermal water in Utah: a compilation of data for thermal wells and springs through 1993, by R.E. Blackett, 74 p., 2 pl., 1:750,000, July 1994 OFR-311 .... **$9.00**
1 disk in Quattro Pro 4.0 for PC, 8/1994 OFR- 311DF **$4.00**

PI-24 Liquefaction-potential map for a part of Davis County, Utah, by J.L. Jarva, 1 p., 8/94 .... **FREE**

PI-25 Liquefaction-potential map for a part of Salt Lake Co., Utah, by J.L. Jarva, 1 p., 8/94 .... **FREE**

PI-27 Liquefaction-potential map for a part of Weber County, Utah, by J.L. Jarva, 1 p., 8/94 .... **FREE**

PI-28 Liquefaction-potential map for a part of Utah County, Utah, by J.L. Jarva, 1 p., 8/94 .... **FREE**

Interim geologic map of the Wales quadrangle, Sanpete County, Utah by T.F. Lawton and M.P. Weiss, 94 p., 2 pl, 1:24,000, Nov 94 OFR-312 .... **$10.20**

A geologic tour through Wasatch Mountain State Park, by J.B. Willis and G.C. Willis, 66 p. + 8-page color insert, December 1994 MP-93-6 .... **$7.95**

Earthquake ground shaking in Utah, by G.E. Christenson, 4 p., Nov 1994 PI-29 .... **FREE**

Geologic map of the Lucin NW quadrangle, Box Elder County, Utah, by D.M. Miller and C.G. Oviatt, 14 p., 2 pl., 1:24,000, 1994, Map 158 .... **$6.00**

Geologic map of the Pilot Peak quadrangle, Box Elder County, Utah, and Elko County, Nevada, by D.M. Miller and A.P. Lush, 25 p., 2 pl., 1:24:000, 1994, Map 160 .... **$6.00**

Quaternary geologic map of the Old River Bed and vicinity, Millard, Juab, and Tooele Counties, Utah, by C.G. Oviatt, Dorothy Sack, and T.J. Felger, 24 p., 1 pl., 1:62,500, 1994, Map 161 .... **$6.00**

Geologic map of the McCornick quadrangle, Millard County, Utah, by F.D. Davis, 13 p., 2 pl.,1:24,000, 1994, Map 165 .... **$6.00**

Oil and gas drilling in Utah, 1990, by T.C. Chidsey Jr., C.D. Morgan, and M.D. Laine, 30 p., 1994, C-86 .. **$5.00**

Interim geologic map of the Fisher Towers quadrangle, Grand County, Utah by H.H. Doelling, 81 p., 3 pl, 1:24,000, Jan 95, OFR-313 .... **$11.00**

The resinite resources of selected coal seams of the Book Cliff and Wasatch Plateau coal fields of central Utah, by D.E. Tabet, B.P. Hucka, and S.N. Sommer, 19 p., Jan 95 RI- 225 .... **$2.50**

Coal in the Straight Cliffs Formation of the southern Kaiparowits Plateau region, Kane County, Utah, by R.E. Blackett, 15 p., + 15 p. appendix + 1 pl. 1:162,000, 2/95 OFR- 314 .... **$4.00**

Geological control of springs and seeps in the Farmington Canyon Complex, Davis County, Utah, by R.K. Skelton, 98 p., 2/95 CR-95-1 .... **$8.00**

Watershed characteristics contributing to the 1983-84 debris flows in the Wasatch Range, Davis County, Utah, by W.K. Coleman, 164 p., 2/95 CR-95-2 .... **$12.50**

A probabilistic investigation of slope stability in the Wasatch Range, Davis County, Utah, by J.S. Eblen, 98 p., 2/95 CR-95-3 .... **$8.00**

Bedrock structure, lithology and ground water: influences on slope failure initiation in Davis County, Utah, by S.N. Ala, 236 p., 2/95 CR-95-4 .... **$19.00**

Seismosaurous the earth shaker, D.D Gillette, 1994, 205 p., Columbia University Press CUP-1 .... **$39.95**
A warm, very personal depiction of the discovery, scientific work, and methods of uncovering Seismosaurus hallorum. Full descriptions are given of its habits, environment, and gastroliths. With 72 color illustrations and photographs.

Interim geologic map of the Brigham City 7.5-minute quadrangle, Box Elder and Cache Counties, Utah, by M.E. Jensen and J.K. King,109 p., 1:24,000. 2/95 OFR-315 .... **$11.00**

Geologic map of the Sterling quadrangle. Sanpete County, Utah, by M.P. Weiss, 26 p., 2 pl., 1:24,000, 1994 M-159 .... **$6.00**

Geologic map of the Coyote Knolls quadrangle, Millard County, Utah, by Dorothy Sack, 18 p., 2 pl., 1:24,000, 1994 M-162 .... **$6.00**

Geologic map of Swasey Peak NW quadrangle, Millard County, Utah, by Dorothy Sack, 16 p., 2 pl., 1:24,000, 1994 M-163 .... **$6.00**

Geologic map of the Scipio Pass quadrangle, Millard County, Utah, by R.B. Micheals and L.F. Hintze,25 p., 2 pl., 1:24,000, 1994 M-164 .... **$6.00**

Geologic map of the Grayback Hills Quadrangle, Tooele County, Utah, by H.H. Doelling, B.J. Solomon, and S.F. Davies, 22 p., 2 pl., 1:24,000, 1995 M-166 .... **$6.00**

Survey News

For the past year, **Michael Laine** has been working with the Economic Program on the Ferron Sandstone Project funded by the U.S. Department of Energy. He received his B.S. and M.S. from Northwestern University in Evanston, Illinois. Michael has worked as a petroleum geologist in Utah and Louisiana and as a consultant for the Uintah and Ouray Indian Tribes. In addition, he was with the Division of Oil, Gas and Mining for five years and worked previously at the UGS in 1986-87. Mike is now rejoining his family in California.

Sharon Wakefield has been named Software Specialist for the UGS DP group, replacing Vajdieh Marxen.

Lynda Lambert has accepted the position of secretary in the Administration group after being the receptionist for six months.

The Bookstore Manager position was accepted by **Victoria Whitaker** who is a graduate from the University of Utah with a degree in geography. She brings with her experience in advertising and retail management.

UGS Deputy Director **William Lund** was selected as the Outstanding Public Employee from his legislative district by the Utah House of Representatives.

Carol Wittenbach , who has been with the UGS for 5 years, has left to take a new position with the Utah State Corrections.

UGS to Open Cedar City Office

The Utah Legislature approved funding to open a one-person office in Cedar City, in southwestern Utah's Iron County, starting in fiscal year 1996. This will be the first satellite or regional office of the UGS. The need for the office is a result of increasing UGS activity in southwestern Utah in tandem with the area's rapidly growing population. A search is underway for adequate office space. The emphasis of the Cedar City office will initially be on engineering geology, environmental, and ground-water projects.

Paleontological Certification Program Created

At the request of the Utah Friends of Paleontology (UFOP), the Utah Legislature created and funded the Paleontological Certification Act which takes effect July 1, 1995. Under this law, the UGS will administer a program to train volunteers in proper excavation and recovery of paleontological resources. State funding will be used to create the training program with certification fees being used to make the program ongoing. UFOP is a non-profit volunteer organization with more than 200 members in five chapters statewide.

UFOP members often volunteer to help in preserving paleontological finds uncovered during development projects. The availability of a well-trained, efficient cadre of volunteers will help reduce downtime for developers, thus making them more willing to cooperate in preserving valuable paleontological resources. The volunteers also provide no-cost assistance to local and state government agencies.

Paleontology Transfer Approved

Scientific staff of the Antiquities Section of the Division of State History will officially become part of the UGS on July 1, 1995, under a law approved by the Utah Legislature. At that time Dr. David Madsen, currently State Archeologist, will become Manager of the Paleontology and Paleoecology Section at the UGS. Dr. David Gillette will bring his title of State Paleontologist to the UGS, reporting to Dr. Madsen. Additional staff transferred include Martha Hayden, Bill Shaver, and Jeff Hunt. ■

Field work on the Ferron Project

With funding from the U.S. Department of Energy, the UGS leads a multidiciplinary team of researchers who are developing a 3-D oil-reservoir model from the Ferron Sandstone. Heterogenic, fluvial-deltaic reservoirs like the Ferron typically contain the largest domestic oil reserves and the largest quantity of unrecovered oil in developed reservoirs. The excellent outcrops of the Ferron Sandstone Member of the Mancos Shale make the Coal cliffs in east-central Utah a world-class area to study reservoir characteristics. Two years of research remain on this three-year project, so look forward to future Survey Notes issues for summarized results.

Cover photo: East view - UGS geologist Tom Chidsey stands atop the Ferron No. 2 Sandstone. The various rock units in this cliff were measured and described in detail to determine depositional environment and lateral and vertical changes in reservoir characteristics. Photo by Michael D. Laine.

Left photo: West view - Ferron Project team members Kevin Arrington (left) and Doug Folkerson, both rock-climbing experts, hang alongside the Ferron No. 1 Sandstone. Using a gamma-ray spectrometer, they measure natural gamma counts every 6 inches to determine clay-mineral content and permit correlation between outcrop traverses. Photo by Marianne Arrington.

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Survey Notes

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